Radio Construction And Repair Work

LESSON 7X1

SPRAYBERRY ACADEMY of RADIO

ESTABLISHED 1932

PUEBLO, COLORADO

RADIO CONSTRUCTION AND REPAIR WORK

Directions on How to Proceed With Your Receiver Parts

LESSON No. 7X1

This lesson begins your practical radio work. The purpose of this work is to give you both *construction and repair experience.* Thus, from a practical viewpoint you prove the theories presented in your other lessons. This part of your study is of the utmost importance. Do not skip any part of it. Carry out each demonstration in the exact way it is described. If you do this, you will get *maximum instruction value* from this part of your SAR Course. You are going to build radio circuits, and you will learn how to analyze them for *defects,* which will simulate actual radio repair jobs as they are found in the ordinary routine of a repair shop. Thus you will get what amounts to actual *experience,* thereby fortifying yourself to compete with the best radio men. By doing work of this kind you will be miles ahead of the average student of radio who must, over a period of years, work out these things for himself. You should, therefore, give *all* of this work your full attention and try to learn as much as possible from it. *Be sure to perform every experiment.*

WARNING! WARNING!

One of the first and most fundamental things you should learn when working with any electrical device is how to avoid bodily harm from electrical shock. *There is absolutely no danger either to yourself or to others if you will observe a few simple rules.* If these rules are not observed, there is real danger in working with any device operated from electrical power lines.

Here are five rules for you to observe when carrying out the demonstrations that will be described for you—remember, too, to observe the same rules when working with other power operated radio equipment.

1. As a general rule, never make a connection, alteration or circuit change when the power line plug is inserted into an electrical outlet.
2. Make no test or connection to a circuit with pliers or other metal parts in your hands when the power plug is connected to the power line.
3. Do not lift or turn the radio chassis when the power is on.

4. When making tuning or other adjustments while a receiver is operating (some few adjustments must, of necessity, be made while the receiver is operating), use only tools having *insulated* handles and do not touch the chassis or other metal parts of the receiver at the same time you are making adjustments.
5. Do not stand on a damp floor or even on a concrete floor when there is the least likelihood of your body coming into contact with a *live circuit.* If necessary, place insulation on the part of the floor on which you must stand. Use hard rubber or a commercial product such as Masonite directly under your feet. Ordinarily such precaution need not be observed unless the floor makes direct contact to ground and then *only when your body may accidentally touch a live circuit. One side of the* 110-120 *volt power line is connected to the metal chassis of this receiver*—so observe due caution as outlined and do not expose yourself to unnecessary danger.

Observe these few rules and you are not likely to receive an electrical shock. As you get experience, you will find that you will observe these precautions from force of habit.

Upon opening your kit of parts, check the items received with *the packing list* which will be enclosed with the parts. Notify us immediately if any parts are missing. Parts are carefully checked here at the Academy and all tubes are tested before shipping so you should receive everything intact.

The practical work which you will carry out will, in some cases, consist of five parts as follows: (1) Title, (2) Procedure, (3) Observation, (4) Explanation and (5) Conclusion. Most of the demonstrations include directions only. The title of the demonstration will explain the object of the work. The procedure will give step-by-step directions for doing the work. The observation will point out to you the things to *learn and remember* about your work. The explanation will explain facts pertinent to the demonstration. The conclusion will sum up the entire demonstration. The different demonstrations will be varied in character, ranging from mechanical considerations to those of an electrical nature. These are designed to fit in perfectly with your practical work.

Before proceeding with the construction of the superheterodyne receiver, you should arrange *a current controlling device consisting of lamps in series with one side of the line.* Such a device is fairly easy to make and is a very useful substitute tester in these days when manufactured testers are so scarce. Directions for using such a tester are given in your lesson 1R-1. Information relating to the construction of the test lamp unit is given herewith so that you may have all construction details complete in one lesson. Too, it is necessary to use this set-up with the receiver because it employs *a series wired filament circuit* and lamps in series with one side of

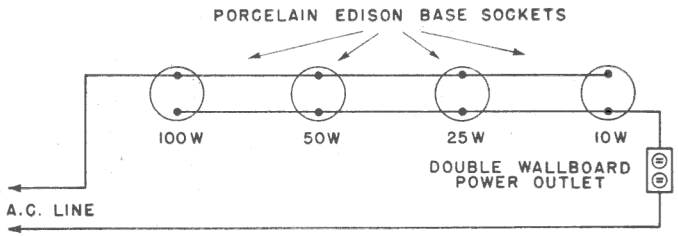

Fig. 1

the power line is one of the most practical and economical means of controlling the line current.

Figures 1 and 2 show the circuit to use. Both circuits are the same, with Fig. 1 showing the pictorial and Fig. 2 the schematic form. As indicating and controlling devices, 110-125 volt incandescent lamps of the ordinary house-lighting variety are used. You will note four lamps are shown. Ordinarily, *only one lamp socket* is used at a time, but four sockets may be used for convenience in changing from one lamp power to another. Figure 3 shows the same basic testing circuit using only one lamp socket. You may use this arrangement if you prefer, but either arrangement will give you the same results. The only difference is that each time you need to change a lamp in Fig. 3 you will have to unscrew one lamp and screw in another, whereas in Fig. 1, it may only be necessary to screw in one more lamp of a different power rating to give a new power rating. Another advantage of Fig. 1 is that from one to four lamps may be used at a time to give different combinations of power. Thus, what follows is based on the use of Fig. 1.

After studying these circuits, you will note that the lamp or lamps are *in series with one side of the power line,* and if a radio set is plugged into the power outlet, it, too, will be in series with the line. *Thus the radio set can draw no more current than the lamp will permit to pass. The lamp, therefore, becomes a controlling device.* Even though the radio has a direct short circuit, no harm will be done because the lamp limits the current which can be drawn from the line. The range of the lamp ratings in Fig. 1 will take care of all ordinary requirements for testing. For the construction of the receiver we recommend the use of one each of the following: 7.5, 15 and a 25 watt lamp. The 7.5 and 15 watt lamp used together as in Fig. 1 will give 22.5 watts while the 15 and 25 watt

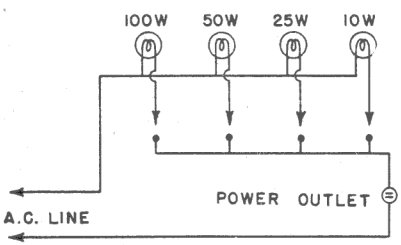

Fig. 2

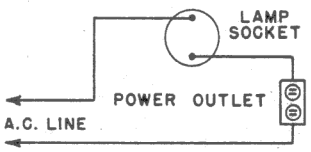

Fig. 3

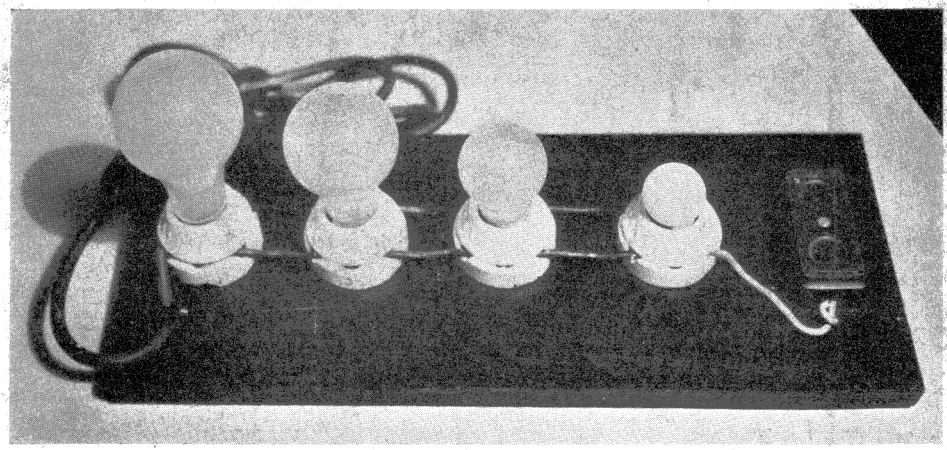

Fig. 4

lamps will give 40 watts and the 7.5, 15 and 25 watt lamps will give a total of 47.5 watts. Assuming a power line voltage of 115 volts, a 7.5 watt lamp will draw .0652 ampere from the line; 15 watts .1304 ampere; 25 watts .217 ampere and 40 watts will draw .3478 ampere. Thus, these are the maxima of current which a *full short circuit* of the radio set under test can cause to flow. Anything less than a full short will cause less current to flow. It is for this reason that the lamps will glow from full brilliance to less than visible light depending on the load placed on them. But no matter what the conditions, ample protection is given the set under test if the right lamp is used.

Figure 4 shows a photograph of the tester or current controller. At the left is shown the usual power line cord. One wire of it is connected to the four porcelain Edison base screw sockets and continues on to one terminal of the double outlet at the right. The other wire of the power cord (not shown; it is underneath the baseboard) connects to the remaining free terminal of the double outlet. The exact electrical connections are shown in Fig. 1.

Demonstration No. 1

Mounting the Tube Sockets

Read the directions of each demonstration before attempting to follow the wiring and mounting instructions. Before beginning the construction work, look over all parts you have received and identify them so that you will be familiar with all you have to work with.

You will notice that the radio chassis is stamped out in a specified shape and of certain dimensions and that the holes for parts are placed in certain relationships to each other and located in this way to perform their several functions to best advantage. You will also notice the holes for screws and for mounting purposes. The chassis mounting holes for the sockets are labeled in Fig. 5 by the type

BC & SW AC-DC RECEIVER

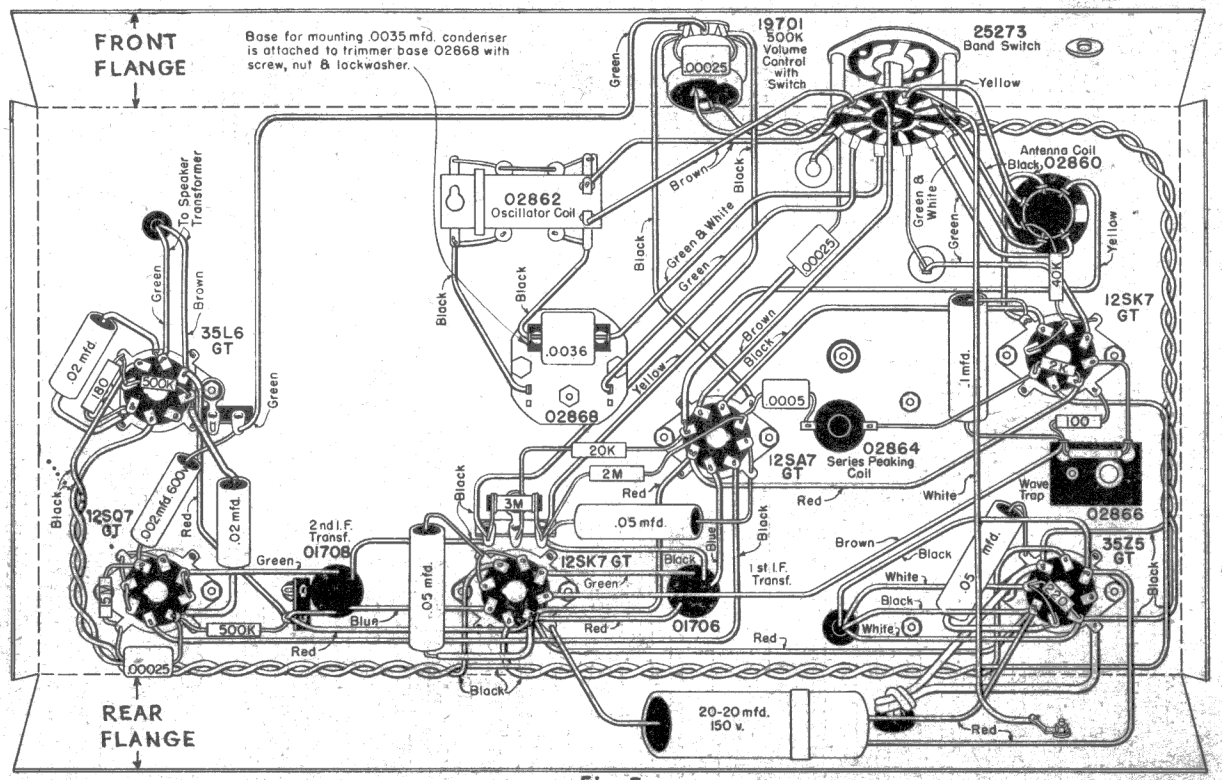

Fig 5

number of the tube which is to fit into the socket. The mounting holes at the left front of the chassis are for the speaker mounting, while to the right side is the location for the tuning assembly. The 3/8 inch hole to the left in the front flange is for the volume control. The center 3/8 inch hole in this flange is for the band switch and the one to the right of it is for the tuning control. Directions for mounting of the various parts will be given as progress is made with the demonstrations.

PROCEDURE

When you become familiar with the mechanical layout of the receiver, take one of the sockets and, after turning the chassis over, place the socket in the hole market 35Z5GT—see Fig. 5. After aligning the screw holes in the socket with the screw holes in the chassis, being sure to place the *keyway correctly,* place a 1/4x6-32 machine screw through the holes in both socket and chassis. Add a lock washer and nut on each and tighten securely. Be sure to observe the relative keyway positions for all sockets in Fig. 5.

OBSERVATION

You will have noticed that each separate part has a particular place in the receiver and that its location is determined to a great extent by the function it is to perform. The tubes are placed with this in mind.

When you have tightened the socket securely with the screws and nuts, you will see that it will withstand the strain of pressing downward necessary to put the tube in the socket as well as to hold it firmly when the tube is being pulled sidewise to remove it. This also keeps undesired parts or terminals from making contact and perhaps causing the receiver to stop operating because of shorting or placing a high voltage in circuits not designed to carry it. Note each tube socket has eight terminals extending from the bakelite part of the socket and there are four more terminals extending from the metal part of the socket. *The latter may be used as grounded soldering lugs since they are common to the metal chassis of the receiver.*

EXPLANATION

Some means must be used to keep parts securely together and to prevent them from becoming loose at any time. Speaker vibration will cause such parts to become loose if they are not secured by some device like a lock washer.

CONCLUSION

For secure mechanical connections, always use some device like a lock washer or some device having a mechanical spring because this is superior to any rivet, bolt or screw. Whenever metal surfaces are involved, there will be opportunity for you to solder connections, add lock washers and tighten mechanical connections for electrical as well as mechanical reasons.

Demonstration No. 2

How to Wire the Filament of the 35Z5 Rectifier Tube

PROCEDURE

(*Read through carefully before connecting to the power line*).

In this demonstration you will learn how to connect the filament of the rectifier tube to the AC power line. You should note at the beginning that a schematic diagram of a radio circuit never appears exactly as the physical arrangement of the actual wiring. The schematic shows the electrical connections or the effective wiring so as to simplify the circuit on paper. However, the connections of the diagram and the actual physical wiring must always agree electrically. In this connection do not attempt to wire the entire receiver by following Fig. 5. A full schematic diagram will be included in the next lesson.

Before attempting the actual wiring take a close look at the bottom of the socket which you have installed on the chassis. You will notice strips of metal protruding from the insulating material of which the socket is made. There are eight of these. They are called tube socket terminals or lugs. They are for the purpose of holding securely the ends of the wires which are soldered to them. They in turn make a good electrical connection with the elements within the tube. Next, and most important, each of these terminals has a definite purpose according to its location on the tube socket. *For this reason it is of utmost importance to get the right wire on the right terminal.* To make an error at this point might mean a burned out tube. To help in avoiding errors and in following directions, each of the terminals on the actual sockets are numbered, as you will observe. Not all sockets in all radio sets are numbered, but they all have a systematic means of identification so as to read the terminals correctly beginning at the keyway.

You will notice a small groove on one side of the center hole in the socket. This is called the keyway, and this is for the pospose of making sure that the tube is mounted only in the correct position. *The tube cannot be inserted in the socket unless the key fits into the keyway.* Now look closely at the bottom of the socket; following a clockwise manner, you will notice that beginning at the keyway the terminals are numbered 1, 2, 3, 4, 5, 6, 7 and 8. Remember looking down on the bottom of the sockets, the terminals of the tube sockets are numbered in a *clockwise direction.* Tubes having these eight terminals are known as octal tubes, from a Latin word meaning eight. All such tubes have their pins and socket terminals numbered in this way.

Now for most octal tubes, the filament terminals are numbered 2 and 7. It is to these that you will now connect the two ends of the power cord. (A note about your wire will not be amiss at this time. Wire is very scarce and hard to obtain. The wire included with this kit is sufficient to wire it as a receiver. However, none is allowed for waste, so use your wire carefully and sparingly. If you can get wire locally, we advise you to

obtain a 25 to 50 foot roll of No. 18 or 20 push-back solid or stranded hook-up wire for you will probably need some extra wire in carrying out the various experiments.) Be sure to use solder to insure a good tight electrical connection. Before making the power line connection you should place the rubber grommet in the ⅜ in. hole, and then feed the power line cord through the hole in the grommet. Tie a knot in the end of the power cord (as shown in Fig. 5) so the wire cannot be pulled tight against its connections. Use of the grommet is to keep the sharp edges of the chassis from cutting through the insulation on the cord and shorting the AC line. Now, after checking wiring, insert the 35Z5GT tube in its socket and plug the power line cord into *a lamp controlled circuit like Fig. 1 or 3. Use a 15 watt lamp.* Next plug the line cord of the lamp circuit into a 110-120 volt AC or DC power outlet *and note that both tube and lamp light.* Figure 6 shows the circuit you will be employing.

OBSERVATION

You will notice that the power is connected to terminals 2 and 7 of the tube socket. The terminals are numbered from 1 to 8 in a clockwise manner. It is most important to visualize this order of numbering since *these numbers do not appear on all sockets.* It is important to see why the ends of the AC line are soldered to the socket lugs. It is first to keep the wires in place in the wiring arrangement and second to maintain a good electrical connection. You should not overlook why the power cord employs a rubber grommet as it passes through to the inside of the chassis. Whenever wires run through metal, this or a similar means of insulation should be used as a protection.

EXPLANATION

Sockets serve as the connecting points between the wired sections of the receiver and the elements within the tubes. The radio man must know that each terminal is for a filament, plate, grid, cathode, screen grid or other tube element. *And he must know which terminal to employ because no errors can be tolerated.* A good soldered connection is a safeguard against radio trouble. To make a good soldered connection heat the part or terminal to be soldered and let the heat of it melt the solder instead of permitting the hot iron itself to do the melting by direct contact with the solder. Too much care in making secure connections cannot be taken. All places where metal is to be insulated from contact with other metal must be carefully observed to guard against shorts, burned-out parts or other possible damage.

Every part and its placement fits into a carefully designed electrical plan and its function cannot be accomplished without close adherance to its proper mechanical placement and arrangement.

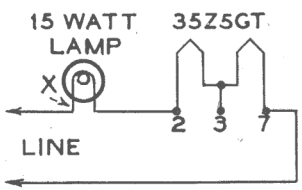

FIG. 6

CONCLUSION

Note in Fig. 6 that the 15 watt lamp is *in series with one side of the power line. This lamp acts as a resistance and controls the amount of current which can flow through the filament of the 35Z5GT tube.* Such an arrangement permits you to operate the filament of the tube direct from the power line even though its filament is rated at only 35 volts. *If you were to connect the power cord directly to the line, the 35Z5GT tube would instantly burn out because the line voltage ranges between 110 and 120 volts.* Thus, you should always remember to never connect a low voltage filament circuit directly to the power line without additional resistance to limit the flow of current. The 15 watt lamp in Fig. 6 provides the extra resistance to reduce the line voltage to about 35 volts. Several tubes may be operated from the line in this way. Later on when all tubes of the receiver are in use, it will be shown that no additional resistance is required because the tubes themselves provide the necessary resistance. In this connection, it should be noted that these conditions apply only to a *series operated filament circuit.* A different set of conditions apply to filament circuits which are operated in parallel from a low voltage secondary of a power transformer.

Demonstration No. 3

Connecting the Rectifier Tube to the Power Line

PROCEDURE

1. Arrange to use a 7.5, 15 and 25 watt lamp in series with the line voltage, using the set-up described for Fig. 1.
2. Connect the lamp circuit to the power line.
3. Insert rectifier tube in socket. Check to see that all connections are correct.
4. Connect the power cord from radio chassis to the lamp control circuit.

OBSERVATION

If you hve a suitable voltmeter you can check the following tabulations. If you do not have a voltmeter, carry out the experiment anyway and note the action of the lamps and tubes. All you need to do is to make the set-up of Fig. 6 and change the lamps starting out with a small 7.5 watt lamp, then using a 15 and finally a 25 watt lamp. When this is done, the following voltages will appear across terminals 2, 3 and 7 of the 35Z5GT tube when the line voltage is approximately 120 volts.

Lamp Power	Terminals 2 and 7	Terminals 3 and 7	Terminals 2 and 3
7.5 watts	4 volts	3.5 volts	1 volt
15 watts	17 volts	14 volts	4 volts
25 watts	35 volts	27 volts	7 volts

EXPLANATION

As you add the lamps in series from 7.5 to 15 and 25 watts, the voltage across the tube terminals will *rise* because the lamp filament of each additional lamp decreases the resistance to the flow of current as the power rating of the lamps increase. With more current flow the voltage drop across the tube filament terminals increase because the resistance of

the tube filament remains approximately the same when hot.

CONCLUSION

Voltage drop increases as the current increases. This, or a similar arrangement of lamps, can be used if necessary to take the place of a burned-out, low voltage secondary on a power transformer if a replacement transformer is not available.

Demonstration No. 4

How to Wire the Power Tube Filament

Place the socket for the 35L6GT tube in the opening in the chassis marked 35L6GT—see Fig. 5. Remove the one power cord connection from terminal 7 of the 35Z5GT tube and connect it to terminal 2 of the 35L6GT tube. Cut a short length of wire pushing back the insulation from the ends and connect it from terminal No. 7 of the 35Z5GT socket to the No. 7 terminal of the 35L6GT socket. Your circuit will then appear as in Fig. 7.

You are now ready to connect the line cord of the radio chassis to the lamps in series with the line voltage. *You must remember not to put the line plug directly into the power line outlet because it will burn out the tube filaments.* Be sure to connect it to the outlet of Fig. 1 which includes a lamp in series with the line voltage.

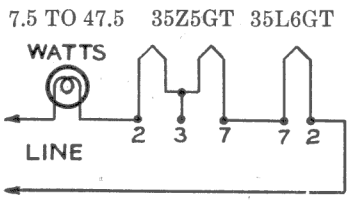

FIG. 7

If you have an AC voltmeter (use a DC meter if your power line voltage is of the DC type), you can easily check the effect of the lamp or lamps as current controlling devices. To do this simply connect your voltmeter across the filament terminals of the tube sockets as different size lamps are tried in the lamp circuit. If you do not have a voltmeter, the following table gives the various voltage values across the 35Z5GT and 35L6GT socket filament terminals as the value of the lamps are changed. Note how well the lamps control the voltage in such a series circuit as the one of Fig. 7.

EXPLANATION

You have doubtless noticed that the voltage drop across the terminals of the two tubes increases as the power rating of the lamps increase. This is due to the fact that as the lamp power increases more and more current is permitted to flow in the circuit which allows more and more voltage drop to occur across the tube filaments. Note that you can only increase the lamp power up to 47.5 watts. A greater increase in lamp power would cause excessive voltage to be dropped across the filaments which means that they would then be overloaded. Remember both the rectifier and power tube are rated at 35 volts. This value cannot be greatly exceded and still have normal tube life. Note for this circuit, 47.5 watts of lamp power permits 36 volts to appear across the 35Z5GT tube and 36 volts for the 35L6GT tube. These values will

Power Rating of Lamp	Voltage Across Terminals 2, 3, and 7 of 35Z5GT	Voltage Across Terminals 2 and 7 of 35L6GT
7.5 watts	2 & 7— 3.8 volts	2 & 7— 3.9 volts
"	3 & 7— 3 "	"
"	2 & 3— .5 "	"
15 "	2 & 7—15 "	2 & 7—15 "
"	3 & 7—11 "	"
"	2 & 3— 3.7 "	"
22.5 "	2 & 7—22 "	2 & 7—22 "
"	3 & 7—17 "	"
"	2 & 3— 5 "	"
25 "	2 & 7—25 "	2 & 7—25 "
"	3 & 7—20 "	"
"	2 & 3— 6 "	"
40. "	2 & 7—34 "	2 & 7—34 "
"	3 & 7—27 "	"
"	2 & 3— 7 "	"
47.5 "	2 & 7—36 "	2 & 7—36 "
"	3 & 7—30 "	"
"	2 & 3— 8 "	"

be obtained when the line voltage is approximately 120 volts.

CONCLUSION

In a series wired circuit, it is important to maintain proper connection for all tubes in the series. With an excess voltage being distributed across various tube filaments, the proper wiring is necessary in order to prevent overload or burn-out of the tube filaments.

The 35Z5GT tube has three filament terminals. These are numbered 2, 3 and 7. Across 2 and 3, the operating voltage must not exceed 7.5 volts and across 3 and 7 it must not exceed 27.5 volts—making a total of 35 volts between 2 and 7. The voltage between 2 and 3 is utilized to operate a pilot light and provide protection for the tube filaments as will be brought out later.

Demonstration No. 5

How to Detect an Open Tube Filament in a Series Circuit

PROCEDURE

Detach one end of the wiring in Fig. 7 from terminal No. 2 of the 35L6GT tube. Then connect the line cord with the lamp in series and observe the two tube filaments for lighting. Then hold the detached end of the wire to the No. 2 terminal momentarily and again observe the filaments for lighting.

OBSERVATION

You will note that the tubes and the series lamp do not light when the wire is detached. But while holding the wire momentarily to terminal 2 you will notice that the tube filaments light up as before.

EXPLANATION

It has been noted that the tube filaments are wired in series; that

is, the filament of one tube is connected to that of the next tube and so on. Because this one tube filament was purposely made open, *the circuit is open for all tubes; therefore, none of the tubes will light.*

CONCLUSION

Thus, you should realize that if an open occurs in *any series wired filament circuit, none of the tubes will light.* Since the heat from the filament liberates electrons which set in motion plate current, you can see why the radio goes dead when one filament in an AC-DC set becomes open. Open filaments commonly occur in small AC-DC radio sets, and you should always be on the lookout for this condition.

Demonstration No. 6

How to Test for Line Voltage

PROCEDURE

It is the usual condition for the voltage of the power line to vary considerably over a 24-hour period because of the varying load on the line. When there is a peak load, the voltage sometimes drops below 110 volts. Too, it will sometimes rise up to 125 or 130 volts. It is important to be able to check the line voltage on certain occasions *because certain unsatisfactory operating conditions in a receiver may be due not to a defect in the receiver but to a low power line voltage.*

The measurement of line voltage is no trick at all when a suitable voltmeter is available. In a circuit like Fig. 6 or one similar to it, to measure line voltage all you need to do is to connect your voltmeter leads (using a suitable meter range) between terminal 7 of the 35Z5GT tube and one terminal of the 15 watt lamp (point marked X in Fig. 6—do not connect the meter to the other side of the lamp.) Of course, if you want to connect your meter directly to the line at the power outlet there is no reason why you should not do so if the terminals of the line are readily available. Without a voltmeter any test of the line voltage you might make is only relative. One good way to make such a relative test in a circuit similar to Fig. 6 (same test may be applied to a fully wired radio set) is to connect low voltage pilot lamps across terminals 2 and 3 of the 35Z5GT tube. Normally, there is a voltage drop across these two terminals of from 3 to 7.5 volts.

OBSERVATION

If, on connecting a 6-8 volt pilot lamp, it lights up to full brilliance and maintains full brilliance, then the line voltage is high. A three volt pilot lamp not brightly lighted indicates low line voltage. There is little, if anything, you can do to correct this condition other than to wait until the line voltage returns to normal.

EXPLANATION

Ordinary power line voltage is assumed to be from 110 to 120 volts for most uses. A variation between 110 and 125 volts is usually not noticeable in the operation of a receiver. A value much lower than 110 volts is usually the cause of irregular operation such as fading, low volume, etc. During the day, the usual line voltage is fairly

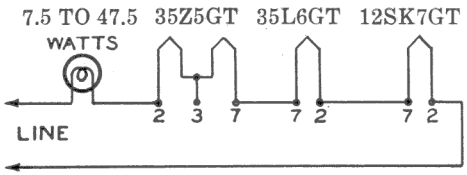

FIG. 8

steady, but at night, when the peak load on the line begins, the voltage of the line *sometimes* decreases. It is normal for the pilot lamp to light to less than full brilliance for a normal line voltage for it has an additional use besides providing light for tuning, as will be brought out later on.

CONCLUSION

When you are called upon to locate the source of trouble in a receiver which is performing unsatisfactorily, it is important to know whether or not the voltage of the power line is at the proper value. If it is low, you will probably have low volume and distortion. So, if at all possible, try to get a check on the line voltage by employing a voltmeter.

Demonstration No. 7

Adding the 12SK7 RF Tube

PROCEDURE

Place an octal socket in the opening for the 12SK7GT tube. Mount the socket as usual. Detach one side of the power cord from terminal No. 2 of the 35L6GT socket. Then connect a short length of wire between terminal No. 2 of the 35L6GT tube and terminal No. 7 of the 12SK7GT RF socket. Then connect the free side of the power cord to terminal No. 2 of the 12SK7GT socket. Now solder these three connections to hold them firmly in place. Figure 8 shows the circuit. Check your work and insert the 12SK7GT RF tube.

OBSERVATION

You will note that one side of

Lamp Power	35Z5GT	35L6GT	12SK7GT RF
7.5 watts	2 & 7— 3 volts	4 volts	2.2 volts
"	3 & 7— 2.8 "	"	"
"	2 & 3— 1 "	"	"
15 "	2 & 7— 9 "	9.4 "	4.6 "
"	3 & 7— 8 "	"	"
"	2 & 3— 3 "	"	"
22.5 "	2 & 7—21 "	20 "	7.2 "
"	3 & 7—16 "	"	"
"	2 & 3— 4.5 "	"	"
25 "	2 & 7—23 "	24 "	10 "
"	3 & 7—18.5 "	"	"
"	2 & 3— 5 "	"	"
40 "	2 & 7—31 "	30 "	12 "
"	3 & 7—24 "	"	"
"	2 & 3— 6.5 "	"	"
47.5 "	2 & 7—33 "	32 "	13 "
"	3 & 7—26 "	"	"
"	2 & 3— 7 "	"	"

the power cord was connected first to the No. 2 terminal of the 35Z5GT socket, then to the 35L6GT, and now it is connected to the 12SK7GT. You will want to follow the directions closely and note that this method of wiring continues to be the case with the remaining tubes. Check your work carefully and, after doing so, connect the power cord to the lamp circuit. The voltage readings across the various tube terminals with a line voltage of approximately 120 volts should check very closely with the accompanying table. (Be sure to make this experiment even if you do not have a voltmeter, and note the effect on the lamps and tubes.)

The same increase in voltage with an increase in lamp power is observed here as in the previous demonstration. You should study the voltage readings in this and the next demonstrations. Note the lamps will control three or more tubes just as easily as they will control one tube. Note, too, as more tubes are added in the series circuit, the lamp power must be increased to maintain the rated voltage across the tube filament terminals.

EXPLANATION

As each tube is added to the circuit, the total line voltage with a value of 120 volts is distributed among the filaments of a larger number of tubes. For instance, with 47.5 watts of lamp power in use, the sum of the voltage drops across the three tubes is equal to 33+32+13 or 78 volts. This means the voltage drop across the 47.5 watts of lamp power is 120−78 or 42 volts which accounts for the total line voltage of 120 volts. It will be an interesting observation to make to see what effect the number of tubes has on the voltage drop as more tubes are added to the circuit. It will probably serve as a hint during your experiments that you *must not* connect the power cord directly to the power line until you have placed all six tubes in their sockets and wired them for series operation.

CONCLUSION

Each tube filament is an added resistance in the circuit, and as long as the filaments are wired in series, their resistances add one to the other for a total resistance value equal to their sum.

Demonstration No. 8

Wiring the 12SA7 Converter Tube Filament

PROCEDURE

Place the socket for the 12SA7GT in position. Tighten the mounting screws firmly and locate terminals No. 2 and 7 of the tube. Remove the power line connection from terminal No. 2 of the

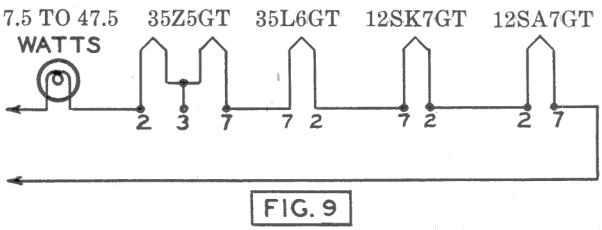

FIG. 9

Lamp Power	35Z5GT	35L6GT	12SK7GT	12SA7GT
7.5 watts	2 & 7— 3 volts 3 & 7— 2.8 2 & 3— 1	5 volts	1.8 volts	2.2 volts
15 "	2 & 7—14 " 3 & 7—12 2 & 3— 2.8	15 "	4.6 "	4.4 "
22.5 "	2 & 7—19 " 3 & 7—17 2 & 3— 4.2	20 "	6.2 "	6 "
25 "	2 & 7—21 " 3 & 7—18 2 & 3— 4.8	22 "	6.8 "	6.8 "
40 "	2 & 7—28 " 3 & 7—22 2 & 3— 6	27 "	8.8 "	8.4 "
47.5 "	2 & 7—29.5 " 3 & 7—24 2 & 3— 6.4	28 "	9.2 "	9 "

12SK7GT RF and connect this to No. 7 of the 12SA7GT. Then connect a wire to the No. 2 terminal of the 12SA7GT, and connect the other end of this to No. 2 of the 12SK7 RF tube. Check back over your work now to see that you made the connections in accordance with the directions. Figure 9 shows the circuit you should have. Insert the 12SA7GT tube and connect to the lamp circuit.

OBSERVATION

The voltage readings across the terminals of the four tubes should closely correspond to the values as given in the next table. Compare voltage drops for each tube in this demonstration with the voltage drops for each tube in the last demonstration. Refer to the voltages for each tube for the lamp power from 7.5 to 47.5 watts. How do they compare? What differances if any do you notice? Are the voltages remaining the same for each tube added or are they changing to higher or lower values? Write down your findings in a note book and check them against comparable readings for the next tube.

EXPLANATION

The values of the first tube filament resistances in series so far are 233.3 ohms for the 35Z5GT, 233.3 ohms for the 35L6GT and 84 ohms each for the 12SK7GT and 12SA7 tubes, making a total of 634.6 ohms. The value of the resistance of the lamps in series must be added to 634.6 to give the total resistance involved. The lamps change resistance when they become lighted to full brilliance. Their hot and cold resistance values are entirely different values.

CONCLUSION

The voltage in this series circuit is equal to the current multiplied by the resistance. Ohm's law applies here in that E=IR. The amount of current these tubes are

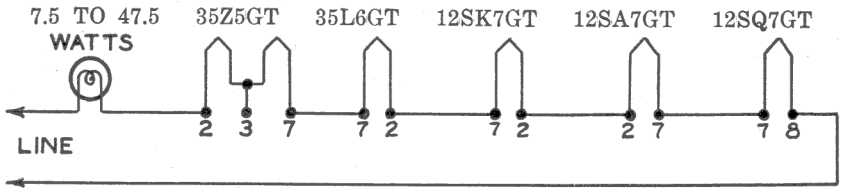

FIG. 10

designed to carry is .15 ampere. The voltage drop across each resistance or tube filament can always be determined by multiplying the resistance value by the value of the current in amperes.

Demonstration No. 9

How to Wire the Filament of the 12SQ7 Detector-Audio Frequency Tube

PROCEDURE

Note carefully the directions for this demonstration. First mount the octal socket for the 12SQ7GT tube. See Fig. 5 for the approximate mounting position. Disconnect one side of the power cord from the No. 7 terminal of the 12SA7GT socket and temporarily connect it to terminal 8 of the 12SQ7GT socket. Now solder a short length of wire to the No. 7 terminal of the 12SA7GT socket and connect the other end to the No. 7 terminal of the 12SQ7GT (not to the No. 2 terminal as for the other tube sockets). *Note the filament terminals of the 12SQ7GT tube are Nos. 7 and 8.* It is imperative to keep this in mind because this indicates that the other terminals are numbered differently for the plate, cathode and grids. After checking again over the directions, insert the 12SQ7GT tube in the socket and connect the power line

Lamp Power	35Z5GT	35L6GT	12SK7RF	12SA7	12SQ7*
7.5 watts	2 & 7— 4 volts 3 & 7— 3.6 2 & 3— 1	4.2 volts	1.2 volts	2 volts	1.8 volts
15 "	2 & 7— 8.6 " 3 & 7— 7 2 & 3— 3	10.2 "	3.8 "	4.2 "	4.2 "
22.5 "	2 & 7—15.4 " 3 & 7—14.8 2 & 3— 3.8	17 "	5.6 "	5.6 "	5.7 "
25 "	2 & 7—20 " 3 & 7—16 2 & 3— 4.2	20 "	5.8 "	6.2 "	6.2 "
40 "	2 & 7—25 " 3 & 7—20 2 & 3— 5.4	25 "	7.2 "	7.4 "	7.8 "
47.5 "	2 & 7—26 " 3 & 7—20.2 2 & 3— 5.8	27 "	7.7 "	7.9 "	8.2 "

*Note 7 ad 8 are filament terminals for the 12SQ7GT tube instead of 2 and 7.

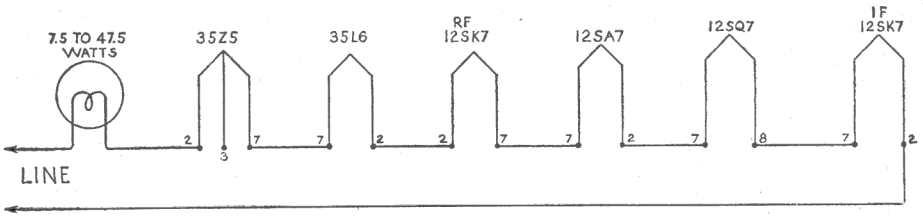

FIG. 11

cord to the lamp circuit. Figure 10 shows the circuit.

OBSERVATION

The filaments of all five tubes are now wired in series and the tubes should be in their respective sockets. You will note that three of the tubes have a 12 volt filament and two of them have a 35 volt filament. This sums up roughly to the effective voltage of the power line. If the line voltage was exactly 106 volts, each tube in this series circuit would have its rated voltage *if the circuit was connected directly to the line without the lamp circuit.* Such tubes are rarely operated at their exact rated voltage because the filament resistance characteristic varies over wide values. Consequently, the voltages to be observed from this and other experiments may be less than rated value.

The voltage drop across the terminals of all five tubes should be approximately the same as that listed in the table on page 16, for a line voltage of 120 volts but still using the lamp circuit as before.

EXPLANATION

The voltage drops across the tube filaments now tend to stabilize according to the resistance of the five filaments in the circuit. The variation of voltage drops is still in direct ratio to the amount of resistance in the circuit. After you have wired the pilot light in parallel with the 2-3 part of the filament of the 35Z5GT tube and connected the 220 ohm resistance, the entire voltage distribution should be normal for this type of circuit, except for the effect of the rectified current which will be explained later.

CONCLUSION

All resistances included within a series wired filament circuit are for the purpose of bringing about the correct voltage drop across each tube filament. The total voltage drops are approximately equal to the effective total power line voltage. Thus, it may be seen that from an Ohms law viewpoint a hot filament may be considered as any other resistance.

Demonstration No. 10

Wiring the 12SK7 IF or Sixth Tube

PROCEDURE

Mount the sixth octal socket for the IF stage, referring to Fig. 5 for a view of its relative position. So far you have included five tubes consisting of the 35Z5, 35L6, 12SK7 (RF), 12SA7 and 12SQ7.

Lamp Power	35Z5	35L6	12SK7RF	12SA7	12SQ7	12SK7IF
7.5 watts	2 & 7— 4.2 volts 3 & 7— 3.8 2 & 3— .8	4.8 volts	1.8 volts	1.9 volts	2.1 volts	1.8
15 "	2 & 7—11 " 3 & 7— 8 2 & 3— 2.9	13 "	4.8 "	4 "	4.1 "	4
22.5 "	2 & 7—15.2 " 3 & 7—14.8 2 & 3— 3.6	17 "	5.2 "	5.2 "	5.4 "	5.6
25 "	2 & 7—19 " 3 & 7—15 2 & 3— 4	19.8 "	5.5 "	5.6 "	5.8 "	5.8
40 "	2 & 7—23 " 3 & 7—18 2 & 3— 5	23 "	6.8 "	6.9 "	7 "	7.2
47.5 "	2 & 7—24 " 3 & 7—19 2 & 3— 5.3	24 "	7.1 "	7.3 "	7.3 "	7.6

You are now ready to connect the sixth tube in the series filament circuit. To do this connect your circuit as in Fig. 11. Remove the power line connection from N. 8 of the 12SQ7 socket and connect it to No. 2 of the 12SK7 (IF) socket. Then connect a wire from No. 8 of the 12SQ7 to No. 7 of the 12SK7 socket.

OBSERVATION

The filaments of all six tubes are now wired in series. The circuit could now be connected directly to the power line. However, there are several observations you should make before doing this. So it is well to use your test lamp circuit again to demonstrate that it still has useful control over the circuit. Make the test lamp set-up as before—connecting it to the power line and plugging in the plug from the receiver into the outlet on your test lamp board. With this done, the voltage distribution across the various tube filaments will be according to the accompanying table with a line voltage of approximately 120 volts.

EXPLANATION

The tubes while under the control of the lamps still do not show their rated voltage drops. A larger lamp rating than 47.5 watts would allow more voltage to be applied to the tubes, but this will not be necessary for further on it will be shown that the tubes may be operated directly from the line—but still under rated voltage, as will be explained. You have probably noticed considerable variation in values in the tables presented in this lesson. There are several reasons for this. For instance, in making our measurements, different degrees of heat were reached by the tubes. Since the resistance of both the lamps and tube filaments changes with temperature, this introduces a non-proportional factor which will account for variations in the tables, and this will also ac-

count for any slight differences you may note in making your own measurements. The AC voltmeter we used in making measurements for the tables included two ranges of 0-10 and 0-50 volts. These have different impedance values, and, consequently, there might be as large a difference as 2 or 3 volts when measuring the same voltage with the two different scales of the meter. Also, if you compare your measurements with ours, you may not get the same exact values as we did because of using a meter of different impedance. All of these possible variations can account for considerable difference when comparing your measurements with ours so you should keep this in mind.

CONCLUSION

If you have followed the details of the previous demonstrations carefully, you will have, by now, come to appreciate the virture of the incandescent lamp as a protective device. You will note it is automatic in its control action and affords full protection to what may be termed a *fragile circuit* which does not, of its own accord, include enough resistance to prevent damage as a result of the application of the full line voltage. Because it is such a wonderful protective device, many radio men include a *series lamp circuit* as part of the shop work bench wiring. Thus, if a receiver has a shorted power transformer, defective rectifier tube, shorted filter condenser, etc., no damage can be done to the set because the series lamp limits the current that can flow as explained in the next demonstration.

Demonstration No. 11

How a Short Affects a Series Filament Circuit

Refer to the circuit of Fig 11. Connect its power line plug to your test lamp circuit and use a single 15 watt lamp. When the tubes have heated short terminal No. 2 of the 12SA7 socket to the chassis of the receiver (make sure your test lamp of 15 watts is in use) with a screwdriver blade or other small metal tool. This will short out the last two tubes in the series string (12SK7, IF and 12SQ7). When this is done, note the 15 watt lamp will increase in brilliance.

This is a case of purposely shorting the filament circuit. However, the 15 watt lamp comes into play and protects the remaining four tubes. Had not this lamp been included in the circuit, one or more of the remaining tubes would have burned out. Hence, the object of this demonstration is to point out that you need to be extremely careful when working with series operated filament circuits. A slip of a tool, a drop of solder between a filament terminal and the chassis, a wrong connection or any other type of short circuit can quickly burn out one or more tubes in a series string. However, if you use an incandescent lamp protected circuit with a low watt rated lamp, you are not likely to have this trouble when working on a set of this type.

Demonstration No. 12

Mounting the Combination Volume Control and Switch

Among your parts you will find a combination volume control and

switch. The two terminals on the rear of the unit are for the switch, while the three terminals mounted on the stub of insulation are for the volume control. This control is to be mounted on the front flange of the chassis in the ⅜ inch hole to the left with the front of the chassis towards you. On examining the body of the control, you will find a small and short key on the front side of it. This key fits into the small hole just to the right of the larger ⅜ mounting hole. To mount the unit, extend the shaft of the control through the ⅜ mounting hole from the underside of the chassis and see that the key fits into the small hole to the right. Then place a ⅜ washer on the threaded bushing of the control and apply a ⅜ nut by turning to the right until it is firmly tight. This will effectively hold the control unit in place. You are now ready to permanently wire the switch and the series filament circuit as it will be used to operate the receiver.

Demonstration No. 13

Relative Position of Tubes in Series String

In conducting the previous experiments, we have purposely directed you to connect them in a way which is not the same as the final circuit arrangement will be for receiving signals. Also, we have directed you to connect to the filament terminals as, for instance, 7 to 7, 2 to 2 or from 7 to 2 for a purpose. This was to illustrate that regardless of a tube's relative position in a series string, it will still operate. Also, from a heating viewpoint of the filament, it does not make any difference whether 7 of one tube is connected to 2 of the next tube or to 7 of the next tube. From an operating viewpoint, however it may be desirable in a series string of filaments to place certain tubes in certain positions. Thus, in an AC-DC receiver, the rectifier tube is usually placed in the series string first with the detector tube being the last one in the series string. This is because the rectifier tube is not susceptible to voltage induction from other parts whereas the detector tube is susceptible to induction voltages. Another reason for placing the dectector tube last in the series string is because it will usually heat quicker than will the higher resistance tube, such as the 35Z5 and 35L6. Thus, by the time the other tubes reach their operating temperature, the detector tube will have already reached its operating temperature and thus will be ready to pass on the signal as soon as the tubes will operate.

In your final arrangement of the tubes as they will operate in the receiver, the tubes will be in different positions so it will be necessary to remove all of your previous wiring before proceeding with the final wiring arrangement of the filament circuit.

Before proceeding with the following wiring directions, first remove all of your temporary wiring of the filament circuit. Clean off all old soldering so that it will not interfere with your permanent wiring. Next make a study of Fig. 5 and note which wires are twisted—you will want your permanent filament circuit wiring to be as near like Fig. 5 as possible. Con-

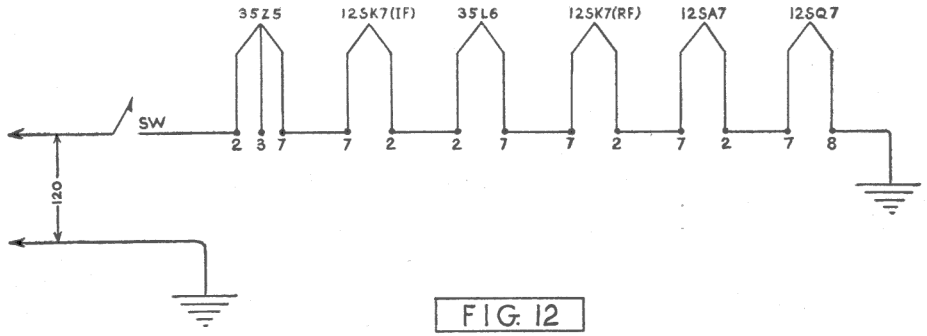

FIG. 12

nect one side of the power line cord to one of the grounded terminals on the 35Z5 socket (in this connection note each of the octal sockets has four grounded terminals as well as eight tube pin terminals). *Next note that terminal 6 of a 35Z5 tube is blank.* Because of this No. 6 on the 35Z5 socket may be used for other purposes. In this case, it is used as a common connecting terminal between the power line cord and the switch. So solder the other side of the power line cord to No. 6 of the 35Z5 socket. Next cut two wires long enough after they are twisted to reach from the switch terminals to the 35Z5 socket, following the path indicated in Fig. 5. Solder one end of these two wires to the two switch terminals as indicated in Fig. 5. Next solder the other ends of these two wires—one to No. 6 and the other to No. 2 of the 35Z5 socket—see Fig. 5. This completes the wiring of the power line cord and also that of the switch. For the rest of the series circuit, connect No. 7 of the 35Z5 to No. 7 of the 12SK7 (IF); connect No. 2 of the 12SK7 (IF) to No. 2 of the 35L6; connect No. 7 of the 35L6 to No. 7 of the 12SK7 (RF), connect No. 2 of the 12SK7 (RF) to No. 7 of the 12SA7; connect No. 2 of the 12SA7 to No. 7 of the 12SQ7; and, finally, connect 1 and 8 of the 12SQ7 to one of the grounded terminals on the same socket. When this wiring is all finished, your circuit should correspond to that of Fig. 12. If you have followed wiring directions as outlined, one side of the line will be wired as follows: from one side of power line to SW (switch) to 35Z5, to 12SK7 (IF), to 35L6, to 12SK7 (RF), to 12SA7 and to 12SQ7. Terminal 8 of the 12SQ7 is grounded and so is one side of the line. Consequently, a complete circuit exists between these two grounded points.

Next, note terminal 3 of the 35Z5 is still free or not connected. This section of the filament (2-3) provides approximately 7.5 volts to light a pilot bulb. To provide pro-

35Z5	12SK7(IF	35L6	12SK7(RF)	12SA7	12SQ7
2 & 7—29 volts	12	32	13	13	13
3 & 7—24 "					
2 & 3— 7 "					

tection from current surges for the pilot bulb and the 2-3 section of the 35Z5 filament a 220 ohm parallel resistance is used between 2 and 3 of the 35Z5 socket. This resistor is color coded red-red-brown. You should now solder it between 2 and 3 of the 35Z5 socket (the pilot bulb will be added later). With this done, check back over your wiring carefully to make sure it conforms to Fig. 5. With this done, you are ready to connect the circuit directly to the power line *without the protective lamp circuit.*

Demonstration No. 14

Operating the Filaments Directly From the Power Line

First see that all tubes are in their proper sockets and that no ground or short exists along the series filament circuit. Now plug in the power line cord and turn the switch knob to the right. This should cause the tube filaments to light normally. With this done the following voltage drops should appear across each tube filament after they have reached operating temperature.

If these voltage drops are added (29 + 12 + 32 + 13 + 13 + 13) they total 112 volts—a difference of 8 volts from 120 volts. This difference is accounted for mainly in that extremely accurate readings were not taken from the AC meter used to make the measurements. You will note the last three tubes in the series string show 13 volts or .4 volt over their rated value. The circuit is not yet completely equalized because the effect of the pilot bulb is not yet included in the circuit nor is the effect of part of the rectified current flowing between 2 and 3 of the 35Z5 tube included. When these two effects are included in the circuit, the entire filament circuit will stabilize and operate at about the rated values.

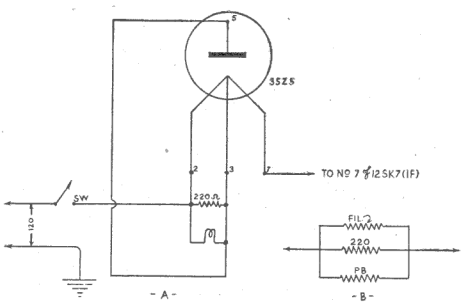

FIG. 13

Demonstration No. 15

Plate Circuit of 35Z5

You have already connected the 220 ohm resistor between 2 and 3 of the 35Z5 tube. To wire the plate circuit of the 35Z5 rectifier tube, connect a short insulated wire from 3 of the 35Z5 socket to 5 of the same socket. Later you will connect the pilot light between 2 and 3 of the same socket—it need not be done now as it will be in you way while finishing the wiring. This is a good time, however, to conside its effect. With the connection between 3 and 5 and with the pilot bulb connected between 2 and 3, your circuit will appear as in Fig. 13A. If it is assumed that a 7.5 volt drop occurs across 2 and 3 of the 35Z5 tube, its resistance will be equal to $\frac{7.5}{.15}$ or 50 ohms. The pilot bulb is rated at 6.3 volts (it will operate on higher voltages up to 8 volts) and .15 ampere and its resistance is equal to 42 ohms. Thus in Fig. 13B these three re-

sistors (the 2-3 section of the filament, the pilot bulb and the 220 ohm resistors) are connected in parallel to give an effective value of about 20 ohms. Thus the *2-3 section of the rectifier filament is made to reduce from 50 to 20 ohms.* This lowered resistance allows more current to flow—the extra amount being rated in milliamperes and is the amount of rectified current drawn by the cathode-plate of the rectifier. When current is first turned on the rectifier tube will not immediately draw plate current until the cathode becomes hot nor do the filaments of all of the tubes draw their rated current until they become hot. As a result of this action and because of the series circuit (low net resistance) the voltage across each tube filament in the string can and will rise to higher than rated values. Of course, this lasts for only a few seconds, but it can shorten tube life and may burn out one or more tubes—particularly those rated at 12.6 volts. This tendency for voltages to momentarily rise above rated values can be controlled by the use of the tapped filament—pilot bulb—220 ohm resistor arrangement. They are in parallel—the pilot bulb and tube filament resistance values being lower than rated value when current is first turned on with the 220 ohm value remaining practically constant. Thus the 220 ohm constant effect is predominant with the net resistance value being lower than normal. As the tubes become hot, their resistance increases, the net parallel value of the rectifier filament increases or becomes normal and the tubes draw their rated current with normal voltage drop occurring across them. The pilot bulb filament is particularly effective in adjusting itself to take care of voltage surges. Its filament is thin and thus it heats quicker than the tube filaments. Because of this, if there is a current surge as when power is first turned on, the pilot bulb will increase in brilliance—then when the tubes get hot the pilot bulb will decrease in brilliance—finally, when the cathodes get hot and begin to draw current the pilot bulb will again increase in brilliance showing that part of the rectified current is flowing through it. Remember the three parallel paths—they each conduct a part of the regular filament current as well as part of the rectified current.

If the pilot bulb should burn out, the circuit will revert from one with a normal resistance of 20 ohms to one with a new value equal to $\frac{220\times50}{220+50}$ or about 40 ohms. This decreases the amount of current that can flow and the fact that the pilot bulb has burned out does not decrease the circuit resistance as could be the case in many AC-DC circuits. Since the pilot light filament is fragile and thin, it, in general, will burn out before a tube will. For this reason, no AC-DC circuit should be allowed to operate long if a pilot bulb is designed to be used—it is always a protection to the rest of the circuit. Later on, instructions will be included when to connect your pilot bulb, and it will be shown how it is affected by the plate cur-

rents of the other tubes in the receiver.

Demonstration No. 16

Rectifier Plate Circuit Filter

If you have carried out the previous instructions your filament circuit for all tubes should now be complete except for the pilot bulb. Also, the plate circuit wiring for the rectifier tube should be complete from 3 to 5 on the 35Z5 socket. To complete the rectifier plate circuit wiring, connect a .05 mfd. condenser from 3 or 5 of the 35Z5 socket to ground using one of the grounded terminals on the same socket—see Fig. 5. As you make your connections make sure to obtain good soldered joints. Get the joint hot enough to melt solder, and you will always be sure of a good connection.

The purpose of the .05 mfd. condenser is to filter and remove large current surges and other electrical disturbances that may come in over the power line. It will not remove all such disturbances but it will be very effective in removing most of them. If it should happen that some of your condensers are rated at a higher voltage than called for in the parts list, it will be all right to use them. A condenser with a higher voltage rating simply provides an extra safety factor with the same capacity rating.

In the next lesson in this series, you will take up further construction of this receiver. In this connection, do not try to wire the entire receiver from Fig. 5. The next lesson (7x2) contains a complete diagram for you to follow.